Ward

Ward

RADIOGRAM BY DR. McINTYRE.
The Human Heart, in situ.

'RACTICAL

;ADIOGRAPHY:

A HAND-BOOK OF THE APPLICATIONS OF THE
X RAYS.

BY H. SNOWDEN WARD,
Editor of *The Photogram*,

'ITH CHAPTERS BY E A. ROBINS AND A. E. LIVERMORE.

With many illustrations.

Published for **The Photogram, Ltd.,**

AWBARN & WARD, LTD., 6, FARRINGDON AVENUE, LONDON, E.C.

1896.

CONTENTS.

PRINCIPAL ILLUSTRATIONS.

INTRODUCTION.

THIS little hand-book is based upon the questions asked after my lecture-demonstrations on the subject of Radiography. The questioners have been photographers insufficiently acquainted with electricity, electricians insufficiently acquainted with photography, and surgeons insufficiently acquainted with both subjects.

The work is so young—Prof. Röntgen's paper appeared as recently as January, 1896—that we are far from having reached finality in regard to the methods of working. Should future editions of this book be demanded, I shall endeavour to include the latest fully authenticated results, and for this purpose I shall be greatly obliged if those who are working upon the subject will keep me advised of any particulars they may publish.

The Photogram, from month to month, devotes a portion of its space to Radiography, and the staff will be very pleased to give any information that is obtainable to any enquirer who encloses stamped envelope for reply.

At the same time, I should strongly recommend anyone who wishes to practise Radiography, and who has not already a fair knowledge of electricity, to carefully read up that subject. There is no better book for the

purpose than Electricity and Magnetism, by Silvanus P. Thompson, D.Sc., &c., price 4/6 (London: Macmillan).

Sincere thanks are tendered to the many able workers who have enriched our knowledge of the subject; and especially to those who have communicated early reports of their discoveries—through myself—to the readers of *The Photogram*. The names of these workers occur throughout the following pages.

H. SNOWDEN WARD.

Shadowgraphy, the hybrid but popular title which was introduced to the public in "The New Light," has been dropped in favour of Radiography, a name suggested by Dr. Hill Norris, and commendable for its euphony, correctness, and non-committal to any theory. Radioscopy I suggest in these pages as the only possible name for the work with fluorescent screens.

CHAPTER I.

A Brief History.

IN outline knowledge of the work of Crookes, Hittorf, Hertz, Lenard, Tesla, and others, is almost necessary to an understanding of Radiography. Hence this preliminary chapter, devoted to a brief history of the subject.

As is well known, any ordinary source of electricity, whether a battery, dynamo, friction machine, or what not, has two poles or terminals, relatively described as positive and negative. If these are connected by means of a wire we form what is known as a circuit; and when the battery (etc.) is in action a current of electricity passes along the wire.

If we now cut the wire, the current still tries to pass, and tends to leap across the gap between the cut ends of the wire, in the form of sparks. This is called a **spark gap**, and the length of the gap across which a spark will leap in dry air, is a rough measure of the voltage, or pressure of the electricity.

If the spark gap is surrounded by a partial vacuum, the electric force becomes more easily able to pass, and as the vacuum increases, the electricity is able to leap across an increasingly great distance. The most convenient method of surrounding such a gap with a vacuum, is to fuse wires into opposite ends of a closed tube of glass, and exhaust the air by means of an air-pump.

We thus get the simplest form of **vacuum tube** (Fig. 1).

The wires thus introduced into the tube are called **electrodes**. If a tube (say) twenty inches long is placed in a circuit with an electric tension capable of sparking across (say) two inches of air, there will be no discharge, so long as the tube is full of air, but, soon after the exhaustion commences, sparks will leap across the twenty inches. As the exhaustion continues, the sparks begin to pass so rapidly that there appears to be a continuous thin string of light through the centre of

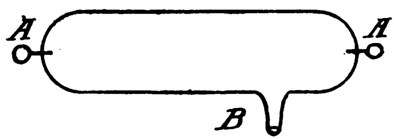

Fig. 1. A.A—glass tube with wires introduced, B. exhaust pipe, to which the pump is attached.

the tube. As the exhaustion proceeds still further, the string of light widens, and becomes less defined, until it appears like a luminous glow, almost filling the tube; and with still further exhaustion the light within the tube almost disappears, while the tube itself commences to glow with a **fluorescent light.**

Many years ago Prof. William Crookes very fully investigated the phenomena occurring in vacuum tubes, and propounded his theory of **radiant matter**. He shewed that, when the exhaustion in a vacuum tube had come down to a pressure of about one millionth of an atmosphere, the molecules of the **residual gas** had a free path in which they could move, without striking each other sufficiently to cause a visible glow in the tube. At this stage, the molecules were strongly attracted to the negative electrode, or **Cathode**. There, becoming negatively electrified, they were thrown off

with great force, and, unless interrupted by some solid object, would strike against the glass walls of the tube. This bombardment of particles caused the glass to rythmically vibrate, and set up the fluorescent glow. This radiant matter of Crookes was afterwards called by other workers the **Cathode Rays**, and, as this is the name generally used, I shall adopt it in this book. Crookes showed, amongst other things:

1. That the stream of particles or Cathode rays, could be deflected by means of a magnet.

2. That the glass tube was capable of **temporary fatigue**, whereby the fluorescence became less and less brilliant as the discharge continued.

3. That a **permanent fatigue** was possible; owing (apparently) to the occlusion of the residual gas particles into the glass of the tube, or the metal of the electrodes.

This work was taken up with great interest by a number of scientific men, who repeated Crookes' experiments, confirmed or contradicted his theory, and carried the investigation some stages further. Most interesting to us is the work of Lenard, a Hungarian, who shewed that cathode rays were capable of passing outside the Crookes tube, and possessed some very remarkable properties. He shewed that they would penetrate aluminium, wood, card-board, and other "opaque" substances, but were stopped by glass, and other "transparent" substances; that they caused fluorescent salts to glow; and that they had a photographic action. Of the last-mentioned property, Lenard took advantage by making photographic negatives, to illustrate the relative transparency of various substances to the cathode rays. But perhaps the most interesting discovery of all was that these cathode rays outside the tube were much less easily deflected by a magnet than those within the tube

In fact, some of them were scarcely deflected at all. The important bearing of these facts will be seen shortly.

Conrad W. Röntgen, a professor at the university of Würzburg, in Bavaria,—and a man who was known to scientific workers for his able and exhaustive researches on several abstruse subjects—was following up this vacuum tube investigation. Working, one day, with a tube covered with black paper (impervious to light), he noticed that a piece of paper coated with a fluorescent salt, and lying at some distance, glowed in the darkness, when the discharge was passing through the tube. Being an investigator on the constant look-out for new phenomena, Röntgen noted the fluorescence, and concluded that some force was passing from the tube, which was capable of penetrating a paper impervious to light, of acting at a distance from its source, and of causing a certain fluorescent salt to glow. From this point he carried out a very masterly series of experiments, to determine the character and properties of these new radiations, which provisionally were called the "X" or unknown rays; "X," in mathematics, denoting the unknown quantity. For a translation of Röntgen's original paper, together with much other matter that is useful to an understanding of the subject, I must refer the reader to "The New Light."* The important items in the paper were the demonstration of the transparency of many "opaque" bodies to **the "X" Rays**, and the photographic power of the rays. The paper gave credit to Lenard for his work, but suggested that the X rays differed from the cathode rays in two directions.

---

* "The New Light, and The New Photography." Fifth edition. Twenty-four pages, super royal 8vo, with twenty six illustrations, including the original paper of Röntgen, and the results of the principal British and Continental investigators during the first few months of the history of the subject.

Aluminium, 1-32in. thick.

Glass, 1-32in. thick. Aluminium lens in brass mount. Tinfoil. Glass, 1-16in. thick.

Penetrability of various substances to the "X-Rays."

A Living Hand.

(An early example).

RADIOGRAMS BY J. W. GIFFORD.

1. That the "X" rays have greater penetrative power: in air and in all substances that they can penetrate.
2. That the "X" rays are incapable of deflection by a magnet.

In the light of the past few months' work, it seems almost certain that Röntgen and Lenard were both working with the same force; but that in Röntgen's case it was produced with more perfect apparatus. In fact, we may conclude that the difference was in degree, rather than in kind, and that Lenard was wrong in supposing that the rays outside the tube were the same as the cathode rays within. This idea is confirmed by an interesting experiment by Prof. J. J. Thompson, in which he shewed that no photographic action took place when a dry plate was placed inside the vacuum tube, and there exposed to the cathode rays.* Practically the only new thing in Professor Röntgen's work was the discovery that bone was much less transparent than flesh to the "X" rays. This fact was seized upon by certain enterprising newspaper correspondents, and to them, rather than to the Professor who did the real work, the "boom" in radiography is due.

The discovery was at once taken up in Britain by A. A. Campbell Swinton, of London; and J. W. Gifford, of Chard. Many other workers who attempted to repeat Röntgen's results were unfortunate in not having, and not being able to obtain, suitable apparatus. Dr. Oliver Lodge, of Liverpool, and Prof. Schuster, of Manchester, went into the subject with a protest against the mere radiographing of skeleton hands and ccins in purses, and an appeal for serious investigation. Other early and successful workers were A. W. Porter, Leslie Miller and Sydney Rowland, in London; Dr. Dawson Turner, in Edinburgh; Lord Blythswood; Dr. J. T. Bottomley and Dr. J. McIntyre, in Glasgow; Professors

* A conclusion since disputed by another investigator.

Chattock and Wertheimer, in Bristol; and Dr. Hall-Edwards and Frederick Iles, in Birmingham. All these reported successful results within a month of Röntgen's original announcement, and they were quickly followed by a whole army of workers.

The simultaneous announcement by Prof. Salvioni, of Perugia, and others, of the "discovery" of the use of a fluorescent screen, directed considerable attention to Röntgen's very first observation on the "X" rays. The practical applications of the screen will be mentioned later.

The tubes for producing "X" rays were the subject of much experiment. Dr. Lewis Jones, of St. Bartholomew's Hospital, designed one in January that answered very well indeed. Innumerable suggestions by various workers were made and tested. In this work much credit was due to A. C. Cossor, of Farringdon Road. In February the "focus" tube was suggested for this purpose by Herbert Jackson, of King's College, and on March 4th its marvellous capabilities were shown at the Society of Arts. The great advantages of this tube caused it to replace, at once, all other patterns.

The next step of importance was the placing of a fluorescent screen in contact with the plate, to decrease exposure, communicated in Britain by A. W. Isenthal; and the only other advance of prime importance up to the date of writing is Dr. McIntyre's discovery, communicated on May 11th to *The Photogram*, that radiograms could be made in an infinitely small fraction of a second, by a single interruption of a mercury contact-breaker.

From this point we must consider the requisites for practical work; and, before giving a description of the apparatus and its use, I think it well to devote two chapters to careful instructions for the manufacture of

the most important apparatus. It is quite possible for a handy workman to make both induction-coil and accumulators. And though, I suppose, very few readers will attempt it, a careful reading of the instructions will be of value in working with these instruments, for a man who does not know their construction is liable to ruin them by misuse.

CHAPTER II.

How to make an Accumulator.

By A. E. Livermore.

THERE are at present **two types** of **storage batteries** in general use, viz., the Planté and Faure. In all cases it is necessary to have at least two plates to form each cell, one positive and one negative. But when the cell consists of more than two plates, it is found advisable to allow the negatives to exceed the number of positives by one, thus preventing an evil known as buckling, which is dangerous on account of its liability to short-circuit the cell.

In the Plante type the plates consist of solid sheets of lead, which are first treated chemically with the object of softening the material, and afterwards subjected to the oxidising and deoxidising action of the electric current, which tends to convert the one plate, connected with the positive pole of the dynamo or current generator and known as the positive plate of the battery, into peroxide of lead, and the other, connected with the negative pole of dynamo, and known as the negative plate of the battery, into spongy lead. The positive plate assumes a dark chocolate, and the negative plate a light grey colour. The process is technically termed "forming," and is an exceedingly tedious and lengthy, not to say expensive, operation.

In the Faure accumulator this process of forming is considerably shortened by the use of lead oxides.

The plates are cast in the form of grids, which act as supports for the lead oxides or active material of the battery. One, and a very convenient form of grid is illustrated in Fig. 2. and a section of same in Fig. 3.; two other sections of various grids may be seen at Figs. 4 and 5.

A mould must be made in which to cast the grids and is shown at Fig. 6.

This can easily be accomplished in plaster-of-Paris. Having made a slab of this material of a size allowing a 2 inch margin all around the edge of the grid to be cast

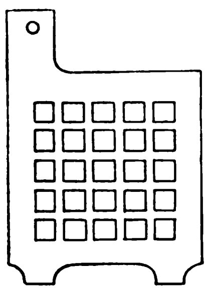

Fig. 2

Fig. 3.

Fig. 4.

Fig. 5.

and from one to two inches in thickness, proceed to draw upon its surface in blacklead a fac simile of the type of grid, as in Fig. 6. The plaster must then be cut away within the marked-off lines to the depth of about 1-16th inches, which may be done with a small chisel. A pouring hole must be made at B, which also forms the lug of the plate, an air hole of the size at C., and a few cuts at DD., at convenient intervals for aligning the cover of the mould when fixing in position for casting. An exact counterpart of the half already cut will be required to complete the mould. To make this, fill up all the grooves in the half already cut, with heated paraffin

wax, pressing it into place with the fingers, and scrape off level with the face of the mould, thus forming a pattern of one side of the grid. When hard, the wax may be removed by inserting a pin at one corner. It will again be necessary to fill in the grooves to prevent the plaster running into them, and scrape off level as before. The impression already taken should next be laid on its back on the wax at present in the groves, and a little shellac varnish applied to the mould with the wax pattern

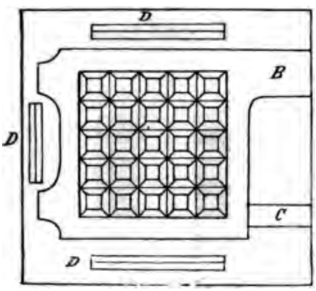

Fig. 6.

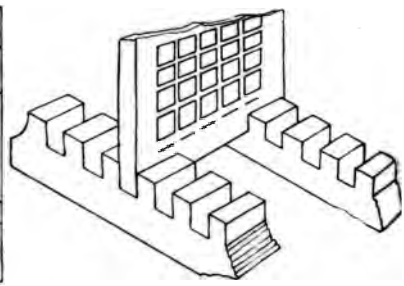

Fig. 7.

in position. A wall of wood must now be arranged around, projecting from 1 to 2 inches, according to the depth of the other half, and the plaster run in. When hard, the mould may be taken apart and all wax removed, the two halves wired together, and the casting proceeded with. The lead used must be pure, and melted in a thoroughly clean ladle, or contamination with zinc or other similar metal might result, which would be fatal. It is advisable to cast a few grids over and above the number required, as some may be found to be defective when the process of pasting is commenced.

Pasting, or filling in the oxides, must now be attended to, the positive grid being filled in with a stiff paste

made of red lead and dilute sulphuric acid (1 part acid to 2 parts water). This is most conveniently done by laying the grid flat on a smooth board and pressing the paste into the perforations (which will be noticed are wedge-shaped for the purpose of holding the oxide as securely as possible in place, and measure ¼ inch square on the surface) with a wooden spatula.

The grid should then be turned over, and the other side similarly treated, when it may be stood on end in a warm place to dry, which will take from 12 to 24 hours. When properly dry, the plate is placed in a concentrated solution of chloride of lime, which gradually converts it into lead peroxide, thus avoiding the necessity of further "forming."

After the action is complete the plate may be rinsed in clean water, and will then be ready for use in the cell.

The negative grid, instead of being pasted with litharge and sulphuric acid, as is usual, may be filled in with precipitated lead. This is obtained in the form of crystals by lowering a strip of zinc into a saturated solution of acetate of lead, the crystals forming on the zinc.

These crystals are very thin, and possess the property of being able to adhere firmly together, forming a soft fibrous and porous mass, which must be gathered and kept under water until sufficient for one grid has been collected, when they may be pressed into same. The plates may now be fitted in their cells, and charged for use, requiring no further forming process.

A very useful form of battery is shown at Fig. 9 the containing vessel being made of teak, lined with ebonite, and divided into six cells by ebonite partitions. Each cell consists of 7 plates (3 positive and 4 negative) each plate measuring 8 by 6½ by 3-16 inches. This

battery has a capacity of 32 ampere hours; viz. is capable of supplying a current of 1 ampere for 32 hours, or 8 amperes for 4 hours, and so on. At the same time it would not be advisable to discharge such a battery as the one here described, at a higher rate than that of 8 amperes. The electromotive force of the battery will be constant at 12 volts, each cell giving 2 volts. It is probably understood that to increase the capacity of an accumulator or storage battery, the size or number of

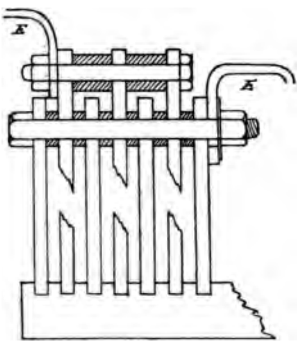

Fig. 8.

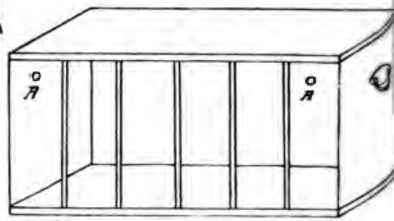

Fig. 9.

plates must be increased, while for greater pressure in volts, more cells are required.

The plates are placed side by side in the cells as in Fig. 8, at a distance of $\frac{1}{4}$ inch apart, and kept separate by means of celluloid or hard wood racks (Fig. 7). In case of the latter being used, they should be previously soaked in paraffin wax. The racks at the bottom are also useful for keeping the bottom of the plates well above the bottom of the containing vessel. This is important, as it allows any active material which may become detached from the plates to fall away clear of them. If this material remained between the plates it

might bridge the narrow gap and thus short circuit the cell. As the negative plates exceed the number of positives in each cell by one, and they are placed in the cell one negative and one positive alternately, the two outside plates will be grey negatives with brown positives next to them, and afterwards negative and positive alternately.

The whole of **the positive plates** in each cell will need to be **coupled together**, the same applying to the negative. The lug of each plate is punched with a ¼ inch hole through which is passed a screwed brass rod, and the plates are firmly fixed by means of nuts and washers, as in Fig. 8. When the plates are thus connected in their cells, the positive coupling of one cell must be connected with the negatives of the adjacent cell, and so on right through the battery. The method of this connection is shown at E (Fig. 8) which represents the form of lead strip used. There will then be a positive coupling or section left at one end of the battery, and the negative section at the other, which are to form the poles of a battery and are best dealt with by soldering them to brass terminal screws which appear on the outside of the containing vessel.

The battery is now ready for **the electrolyte or acid** to be run in, and, for the type of cell here described, sulphuric acid of 1·19 specific gravity will be required. The acid used must be the pure brimstone acid, and none other. This will require diluting with about 4 times its quantity of water to bring it to the abovementioned specific gravity. In mixing, always add the strong acid to the water, not vice versâ, for in the latter case, the mixture sprays violently in all directions. This mixture should well cover the tops of the plates. Directly the electrolyte is run in, charging should be commenced, which may be effected by a small shunt-

wound dynamo, absorbing about ½ horse power, or by the supply of a public company, provided the current be a constant one, an alternating current being unsuitable, or, on the other hand, the cells may be sent to an electrical engineer to be charged.

To use a public supply the following will be required. About one dozen yards No. 18 standard gauge insulated copper wire; an ammeter, which may be borrowed from any electrican for a trifling sum; some Wilkes' pole-finding paper; and a resistance, which may be made as described below. To wire up the company's supply, first switch off current, then unscrew the cap of a ceiling rose, and after marking with chalk the heads of the two screws to which the lamp leads are attached, unscrew them a couple of turns and unhang the lamp. The little fuse wire in the ceiling rose will have to be altered under the advice of an electrician. Next cut two suitable lengths of your insulated wire, clean and brighten about one inch of naked wire at their ends and substitute these in place of the lamp leads, screwing up enough to ensure a tight hold. Now switch on current and apply the other ends of your wires to a piece of the pole-finding paper, not allowing the two wires to come in contact with one another. Note the positive wire (a red spot appearing on the paper at the point where it is touched by the negative wire), and, for the benefit of future occasions, mark the screw in the ceiling rose to which it is attached, the current being switched off again. Break this wire at any convenient place and insert **the resistance**, which may be made follows:—Procure an ordinary sized pudding basin, and a couple of strips platinum about 2½ inches long by ⅜ inch wide. To these strips must be soldered (using resin as a flux) the two broken ends of the positive wire above referred to. Bend the ends of the strips to which the wires are

attached in the form of clips over the rim of the basin, so that their other extremities are immersed in the water (which is to reach about ⅔ up the basin) opposite to one another, the remaining end of the wire being bound to the positive terminal of the battery.

The ammeter will now have to be put in circuit, and may be connected to either of the leads; but as the resistance should be on the positive lead, it would tend to simplify matters if the negative wire were similarly served and the ammeter inserted thereat, the remaining end of the negative wire being joined up to the negative terminal of the battery. This system is illustrated in

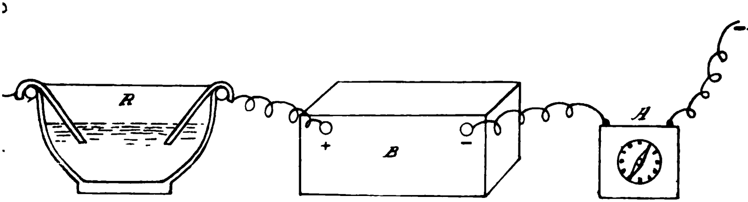

Fig. 10.

Fig. 10, where R represents the resistance, B the battery, and A the ammeter. The circuit thus completed, the current may be switched on, but as the above resistance will be too great to pass sufficient current, sulphuric acid must be slowly added to the basin until from 8 to 12 amperes are indicated on the ammeter, when in a short time, by the evolution of gas, the cells will show they are being charged. If the quantity of water used for the resistance be previously measured, and the acid be added from a measuring glass, the exact proportions of the mixture may be ascertained, and the ammeter will *not be further* required.

The cells should charge evenly, and at the same rate as one another. Elements showing no sign of, or too little development of gas, must be examined for detached particles of oxide making contact across the gap dividing the plates, which particles must be removed by a glass rod until they drop to the bottom.

On the care of the accumulator a few words may be said. A cell should never be completely discharged. When the electromotive force falls to 1·9 volts per cell (which can be ascertained by the use of a voltameter made for the purpose) the discharge must be stopped. Charging should be continued till gas is given off freely from the cell, and the acid acquires a milky appearance. The cell will show an electromotive force of 2·5 volts when fully charged; and the liquid lost by evaporation should be made up by the addition of water. Overcharging is less to be feared than a too rapid discharge. Cells should never be put away empty, or with their plates discharged. They should also be charged at least once in five weeks, whether in use or not. Short circuiting by means of a short stout wire from terminal to terminal, just to see the sparks on breaking contact, will ruin a cell. Be careful always to join the positive supply wire to the positive pole, and the negative wire to the negative pole of the battery to be charged. Jarring should be avoided as much as possible, and with a tolerable amount of care these batteries may be kept in order for an indefinite period.

CHAPTER III.

How to Make an Induction Coil.

By E. A. Robins.

ANY one with an ordinary amount of ingenuity, and some little mechanical skill, can make an induction coil much more cheaply than it can be bought. It has been shown that good radiographic results can be produced with short exposures by a coil giving a spark of about two inches, but it is advisable to use a coil capable of giving a 6 inch spark.

The coil, as represented in figure 11, is composed of a bundle of iron wire, surrounded by two layers of thicker wire, called the primary, which carries the inducing current; and this is again surrounded by a large number of coils of very thin wire, called the secondary, in which the high tension is produced; a contact breaker, and a condenser.

The iron core is composed of well-annealed iron wire, of No. 30, B.W.G. (Birmingham wire gauge), made into a bundle 14½ inches by 1½ inches, made red-hot in a fire and allowed to cool slowly. When cold, the whole bundle, kept together by wires round the outside, is soaked in shellac varnish or melted paraffin wax, until it has penetrated right through. This is to prevent destructive currents being set up in the iron. When dry a layer of cartridge paper, soaked in paraffin wax, is placed round; and over the whole a thin ebonite tube.

On this is wound the **primary** wire, composed of

two layers of No. 12, B.W.G., cotton covered and well soaked in paraffin wax. About four and a half lbs. of wire will be required. A layer is wound on, leaving ends long enough for making the connections, and over this a layer of paraffined cartridge paper, then the other layer of wire, finishing at the end at which the winding started. The primary wire will safely carry eight amperes without heating appreciably, and very likely ten could be used. Over the last layer is placed a layer of paraffined paper, and then a thin ebonite tube.

On this is wound **the secondary coil**, which is best composed in sections, in this coil, eight; but a greater

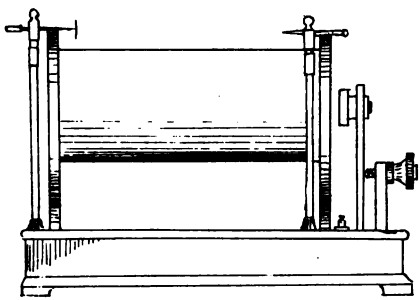

Fig. 11.

number is better. This arrangement, by placing wires having a great difference of potential away from one another, much diminishes the chance of internal sparking, and thus ruining the coil. The wire is No. 36, B.W.G., of which twelve lbs. will be required, silk covered, and the bobbins containing the wire should be soaked in paraffin wax before winding. A pound and a half of wire is wound upon each section, a **"former"** or bobbin *being made* corresponding to a section and having one *side removable*, and may be driven from an ordinary

sewing machine table. Figure 12 will show the method of winding.

The wire is drawn through a hole near the lower part of the former, leaving enough projecting for connections, and the former filled with wire, 1½ lbs. The next is wound in the same way, and the coil turned round before placing upon the core, thus; in two adjacent sections the currents run in the same directions, as will be seen from figure 12; the two inner ends are connected. The third coil is wound and placed like the first, the outer end being joined over the top of the division, with the outer end of the second coil. The fourth is like the

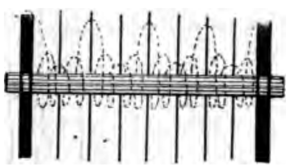

Fig. 12.

second, and has its inner end joined to the inner end of the third, and so on. The eighth coil has one end free and is one of the terminals, the first coil being the other. The coils should be soaked in paraffin wax, the divisions may be thin ebonite of one-sixteenth to one-eighth inch thick, or two or three thicknesses of celluloid, such as is used for the thick photographic films, which I find very useful for this purpose. The ends may be made of ebonite or well-seasoned mahogany about ¾ inch thick. Of course there is no connection between the primary and secondary, if there is, the coil is of absolutely no use. The soldering of joints between the coils should preferably be done with resin, as "killed" acid may corrode the wire and cause heating, and perhaps melting of the

wire. If any break occurs during winding, a join mu be made by twisting and soldering the ends of the wi together; for any break in the wire of the completed c will render it absolutely useless.

The outside should be covered with thin she ebonite, bent round. This prevents sparking on to th coil. The secondary terminals should be supported about eight inches apart, on glass rods. The coil, as it

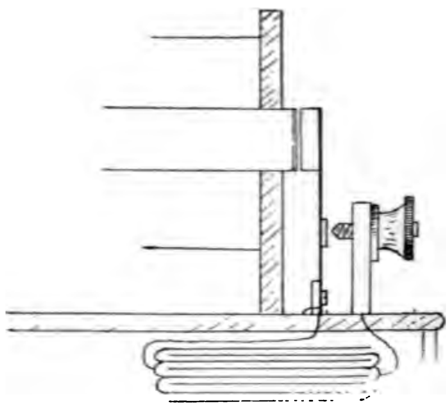

Fig. 13.

is to be used with continuous currents, must have some method of making and breaking the current.

The **contact breaker** may be as in figure 13. A small iron hammer, 1½ inches in diameter, supported upon a spring of brass, having a screw touching against it. The points of contact should be platinum, to guard against corrosion. The hammer is opposite the end of the iron core, and works thus—the current comes from the battery through the screw and spring to the primary coil and back to the battery, this makes the iron core a magnet, which attracts the soft iron hammer, dragging

the spring away from the point of the screw, this breaks the current, the core ceases to be a magnet, no longer attracts the hammer, and spring flies back again, making contact.

The mercury contact breaker is that shown in figure 14. A rod is pivoted in the centre, at one end of which is a platinum point dipping into mercury, on the other is a soft iron armature, below which is an electro-magnet. The current from the battery flows to the mercury up the platinum point, along the rod, down the support, and round the magnet wire, through the primary, and back to the battery. This excites the

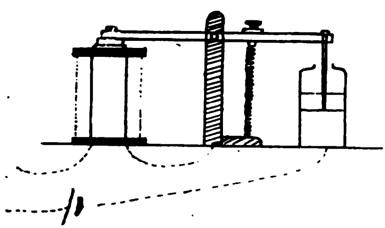

Fig. 14.

magnet which attracts the armature, raising the point out of the mercury, breaking contact, current ceases and the spring pulls the rod down, again making contact. The mercury is covered with a layer of paraffin oil, to prevent sparking, and also oxidation of the surface. For large coils this contact breaker is the best, being more under control.

For continuous currents **a condenser** is required, and is for the purpose of receiving the current induced in the primary on the "break" of the current by the contact breaker, which would otherwise leap across the gap between contact breaker and platinum point, the charge stored up in the condenser also assists the current in

the primary wire on the "make" of the current. It is composed of 200 sheets of tinfoil, 9 inches by 9, having a layer of good paraffined paper of slightly larger size than the tinfoil, between each pair of sheets. The corners of alternate sheets are joined together, and each set is joined to the contact breaker as in figure 13, which shows the condenser in position; the condenser should, when finished, be placed under heavy pressure until the paraffin wax has set. It is most important that no connection exists between the two sets of tinfoil sheets, as this would "short circuit" the contact breaker, and no effect would be produced upon the coil. The end of the primary should be joined to the foot of the spring in the first kind, and to the magnets in the second kind of contact breaker, the screw in the first and the mercury in the second being joined by a No. 14 B.W.G. wire to a large terminal. The other end of the primary is joined to a like terminal, placed about two inches away. The wire on the magnets of figure 14 must be the same as the primary wire. The secondary terminals should be placed as far away as possible from the primary terminal and contact breaker, as a spark from an induction coil such as this would be very dangerous, if not fatal to some people, Sparks should not be taken to the body when above ¼-inch in length. If the current be taken from the lighting mains a variable resistance* must be placed in series with the primary; enough to bring the current down to about six amperes, this being quite enough to run the coil. As this depends upon the size of the house leads, the advice of a competent electrician should be taken before attempting, or the mains may easily get fused, owing to the resistance of the primary being very small, about half ohm.

The coil may be mounted upon an ebonite or ma-

*See preceding chapter, page 23.

hogany base, containing a cavity in which the condenser is placed. If a smaller coil be required, say a two-inch spark, the core should be composed of iron wire (No. 30, B.W.G.) treated as described above, about ten by one inches, the primary wire two layers of No. 16, B.W.G., double cotton-covered and insulated as described above; the secondary is composed of four pounds of No. 38, B.W.G., wound in sections, double silk covered. A hammer contact-breaker should be used for such a small coil as this. The condenser should be about 100 sheets of tinfoil, nine inches by seven.

The wire is, of course, the most expensive article, and should be obtained direct from the manufacturers. The London Electric Wire Co., Playhouse Yard, Golden Lane, E.C., supply it. The materials for the six-inch coil could be purchased for about £5 10s. Of course, this leaves out all labour upon the coil. Some turning will have to be done, and this depends upon the person who is making the coil. The smaller coil will cost about £3 3s. for material; and will give good results with tubes specially made for small sparks, the exposure being somewhat longer than with larger coil and suitable tube. The paraffin wax can be obtained from the above firm, and costs about eightpence per lb. It should not be heated too high, as this slightly destroys the insulating power; it is best heated in a water bath, as paraffin wax melts at about 100° F. The weight of six-inch coil will be about twenty lbs. Shellac varnish can be used for insulating purposes, and the glass pillars of the secondary terminals should be coated with it inside and out if tube be used. Thin wires only are needed for connections to the secondary coil, as the current flowing is extremely small, the potential being very high. But they should be very highly insulated *with rubber.*

CHAPTER IV.

THE APPARATUS

THE whole essentials for radiography are, *(a)* A source of electricity; *(b)* An induction coil; *(c)* A specially made vacuum tube. If using a Wimshurst machine as the source of electricity, the induction coil, by far the most expensive part of the apparatus, is done away with. The fact that under these circumstances, the Wimshurst machine is but little used for the purpose, is explained by the fact that many persons who have tried to use it have utterly failed. Some few workers have been successful and if their results can be repeated with a certainty, it seems likely that the induction coil will be largely superseded. **The Wimshurst** or influence machine (Fig. 15) is well-known to all students of electricity. It has the advantage of only requiring moderate power to drive, and requiring no supplies in the form of acids and other solutions. It gives very high tension electricity without the necessity for an induction coil and is perfectly clean and simple in use. On the other hand, it has the distinct disadvantage of being exceedingly sensitive to climatic conditions. Dust and damp ruin its performance, and to secure the best work of which it is capable, means constant care and protection, and sometimes a good deal of work in warming and drying. Instructions for Wimshurst work are given in the next chapter.

A modified **Bonetti Wimshurst** machine is made by

R. Tudsbury & Sons, specially for radiography, and they guarantee its performance.

The street mains (if continuous current) may be used as the source of electricity in radiography, provided the pressure is brought down by resistance. The current that has worked most successfully in my own

Fig. 15.

experience is three or four amperes, at eight volts, working with a six-inch spark coil. The tyro should have the advice of an electrician in taking off current from the street mains or he may burn out a main fuse or ruin his induction coil. The alternating current cannot *be used.*

Primary batteries of almost any description may be used, but perhaps the most satisfactory are Bunsen cells or bichromate cells. This source of electricity is convenient, safe, and economical, and is all that can be desired by people who have space, and who always intend to work in the same place. A battery of 8 large Bunsen cells or of 6 large bicromate cells will be sufficient.

Fig. 16.

Secondary batteries or **accumulators** are especially convenient for those who may need to frequently move their outfit; as, for instance, surgeons who may wish to work in their own laboratories, with the advantage of being able, at any moment, to move their outfit to the home of a patient. I need hardly describe the construction of an accumulator, as that is fully done in the

chapter by A. E. Livermore, but I may say that it does not, as is commonly supposed, store electricity. As a matter of fact, the electricity passed into the accumulator does chemical work, and changes the chemical condition of the contents, leaving them in such a state that they are always tending to revert to their original condition, and to generate electricity in the process. To enable

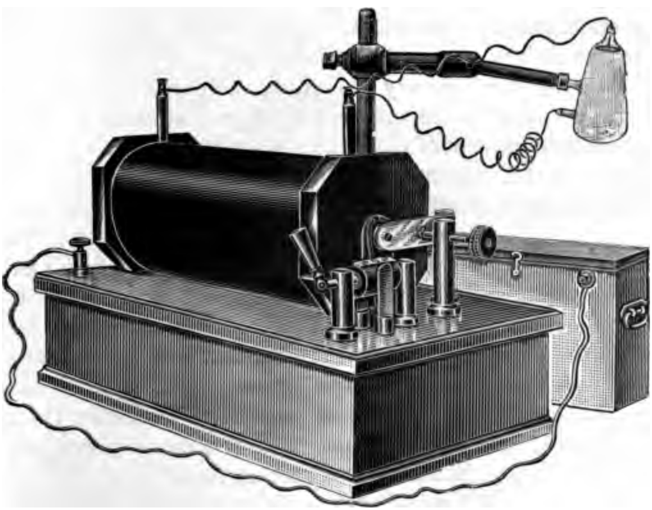

Fig. 17. Coil, Battery, Tube and Stand.

the electricity to be thus generated it is necessary to complete the circuit by laying a wire from the positive to the negative end of the accumulator. Two four-volt accumulators of ten ampere hours capacity, will answer well for radiography. There are many convenient forms of accumulators made; one of the best being a form made by A. Hurst & Co., Fig. 16, and especially designed for running surgeons' and dentists' motors, etc.

The induction coil is a well-known piece of electrical apparatus, which I shall only briefly describe, as its construction is fully explained in the chapter by E. A. Robins. It consists, essentially, of a core of soft iron; round which is wrapped a great number of turns of comparatively thick wire, called the primary coil, or "primary." This is insulated, by wrapping in waxed paper or other insulating material, and surrounded by an enormous number of turns of very thin wire, forming the secondary coil, or "secondary." If electricity is passed into the primary (including the core) it becomes a magnet, and at the moment of magnetisation a powerful inverse current of electricity is set up in the secondary wire. At the moment of breaking connection a powerful direct current is set up. These currents do not continue, so it is necessary to use a "contact-breaker," to very rapidly make and break the circuit. The result of this is, practically, a very powerful alternating current, and as what is practically a direct current is needed for our work, the induction coil is supplied with a "condenser" (see Chap. III.) which is placed in the base. This causes the current induced at "make" to be feebler than that at "break" of contact, and therefore gives us, practically, a continuous or direct current.

The object of the induction coil is to take a current of electricity at a low tension or voltage, and to give us a current at a very high tension or voltage.

The vacuum tubes used in radiography are specially prepared and exhausted and vary enormously in design but they are all alike in the fact that they consist of a bulb of glass from which the air has been exhausted, and into which are introduced at least two pieces of wire or electrodes.

Of these **electrodes** the positive is called anode, and the negative cathode. Various metals can be used for

RADIOGRAM BY A. A. CAMPBELL-SWINTON.

Sole, shewing swimming bladder.

the electrodes, but as most of them disintegrate under the passage of the electric current, and give off very fine particles, which reduce the vacuum in the tube, search is made for the one which has least of this defect, and, as Crookes showed, this is aluminium. As this metal needs to be fused into the glass, and as aluminium has a co-efficient of expansion with heat that is very different from that of glass, a difficulty is at once introduced, for an attempt to fuse the two together results in a crack which prevents the obtaining of a vacuum. This diffi-

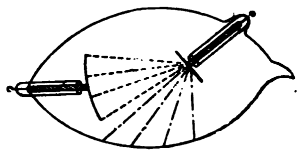

Fig. 18. Focus Tube.

culty may be overcome by attaching to the aluminium a small piece of platinum wire, which will fuse into the glass.

As sodium glass is used for radiographic tubes, on account of its great transparency to cathode and x rays, and as this glass will not fuse into connection with platinum, it is necessary to fuse the platinum into a little bit of lead glass, and to fuse this into the soft soda glass of the tube. This makes a joint between two glasses with varying coefficients of expansion and to make a tube that will stand rapid changes of temperature, it would be necessary to anneal for a long time, raising the annealing furnace gradually to a great heat. As this is impracticable under the present condition of tube-making, it is necessary to treat the vacuum tube with care, and if you need to heat it, to do so very gradually.

Of the many tubes now in use, the only one that need

attract much of our attention is the focus t
tern essentially different from any other. In
alone are the x rays generated by directing th
rays upon a metal surface (platinum). In ot
the cathode rays strike upon glass, at the s
which the x rays are generated, and platinum
to have great advantages over glass for this pur

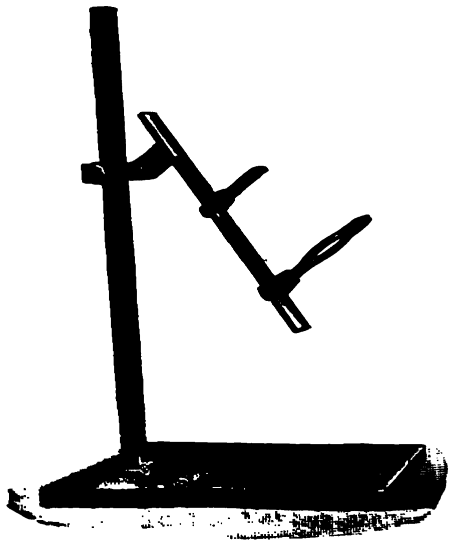

Fig. 19.

A stand of some kind is necessary to ena
the tube to be easily and safely fixed in any desi
position relative to the object to be radiographed.
cheap and convenient form, which will hold any patt
of tube, and which can also be used as a retort hold
test-tube holder, etc., is the well-known Bunsen sta
Another form, specially designed for focus tubes

placed on the market by W. Watson & Sons, and is illustrated in Fig. 19.

A still further piece of apparatus for this purpose is the "exposing box," made by Reynolds and Branson. It consists of a light-tight box for 12-in. × 10-in. plates, with a "carrier" for whole-plate (8½-in. × 6½-in.), attached to which is a stand, with a clip to hold the tube, and a couple of supports above to take the connecting-wires, thus keeping them off the table and out of the way of operator or subject. This arrangement is very convenient, and reasonable in price.

For photographic work, **photographic dry plates** or films are needed, and there so many excellent brands on the market that there need be no difficulty in this matter. I have seen excellent results produced on almost every make of fairly rapid dry-plates. At the time of writing there are some brands specially made for radiography and one of these I have proved by careful quantitative test to be appreciably better than any other plate. On the other hand, some of the "special" plates are very ill-fitted for the work. Many of the plate-makers are busy with experiments, and any day may see considerable improvements. As many good makes are almost equal to the best, I recommend the reader to take any rapid plate that is recommended by a respectable dealer, but not taking the ultra-rapids. My own tests, the results of which were communicated to the Royal Photographic Society on May 12th, 1896, showed that plates of a light-sensitiveness of 75 to 100 on the Hurter and Driffield scale gave better results than those of greater sensitiveness. For work with the fluorescent screen celluloid films have an advantage over plates, as will be seen later.

To protect dry plates from day-light, some cover, impervious to light, but pervious to the *x* rays is needed.

Those who have photographic dark slides may use them, but I prefer light-tight negative bags, because they allow the object to come close to the plate, and so to give clear sharp outlines. They have the further advantage of being very cheap and very portable. There should be an inner bag of stout (usually orange-colored) paper, in an outer bag of black.

Chemicals, developing dishes, etc., will be needed, and to the reader who is not a photographer I would recommend

Apparatus.

2 developing dishes (ebonite or papier-maché).
1 fixing dish (porcelain).
1 graduated glass measure.
1 pair small scales, and weights.

Chemicals.

Pyrogallic acid	1 oz.
Potassium metabisulphite ...	1 oz.
Potassium carbonate	1 lb.
Potassium bromide	1 lb.
Sodium hyposulphite	7 lbs.

This will complete the absolutely necessary outfit, but those who wish to do careful investigation work and to vary and control their experiments, will need an ammeter for measuring the quantity of current passing, and a voltameter to measure the tension or voltage of the current.

CHAPTER V.

Practical Radiography: Electrical.

IN the first instance we will suppose that we are working with an outfit consisting of primary or secondary batteries (accumulators), an induction coil, and a focus tube. The following are the only forms of **primary battery** likely to be used, and they all consist of a positive pole (anode), a negative pole (cathode), and one or two battery solutions :

Name.	Anode.	Solution.	Cathode.
Bichromate ...	Zinc	Bichromate of Potash	Carbon
Bunsen	Zinc	H_2SO_4 HNO_3	Carbon
Daniell	Zinc	H_2SO_4 $CuSO_4$	Copper

The zincs should be cleaned in H_2SO_4 and rubbed over with mercury until a bright surface is obtained.

Where two solutions are given, the one on the right is that in which the cathode must be placed, while that on the left contains the anode. I can only give very general instructions for the care of these cells. If not wanted for a long time the solutions should be emptied out of the jars, and the anode and cathode be carefully wiped. If the latter appear to shew any appreciable deposit of foreign scaly matter they may be scraped. In the bichromate and some other forms of cell, provision is made for lifting the anode and cathode out of the liquid, which should be done whenever the cell is not in use

A number of these cells form a battery, and they can be connected up "**in series**" or **in parallel.** In series we connect the anode of No. 1 to the cathode of No. 2, and so on. In parallel, we connect the cathodes of all the cells to one line of wire, the anodes to another, and complete our circuit by running the wire from an end-cell anode to its own cathode,—through our induction coil or other working apparatus.

Connecting in series, we do not increase the amount of current (the amperage), but we do increase the voltage. In parallel, we increase the amount of current, but not its voltage or pressure. In the same way as we increase the size of our cells we increase the amount of current; but in a cell of given materials the voltage is the same in any size.

The amount of current that can safely be used with a given coil varies according to the coil's construction, and if working with a coil of early date, to which one is not accustomed, it is well to be cautious. Modern coils, for any given spark, are based upon pretty much the same calculations, and for them the following currents will be on the safe side:

2-in. spark coil	5 amperes
6-in. " "	10 "

and other sizes in proportion.

Amperes and **volts**. A simple illustration of the difference between current and pressure (or tension) may be given by the analogue of water. If we have water in a reservoir a thousand feet high, and draw it through a small pipe, we only get a small stream or current, but it is at high pressure or tension. If we have the water of a river flowing with a fall of only a few feet in the mile, we have a great current, but at no great pressure. In the same way, the ampere is the measure of the total amount of electricity passing

while the volt is a measure of the pressure of that current. Thus, we never say a current of six volts, but a current of three amperes (or what not) *at* six volts.

If we are using **secondary batteries** or **accumulators** we shall find in each, at the top, two screw-caps or wire ends, to which to make connections. These will either be marked + (=positive, or anode) and — (=negative, or cathode), or the positive will be painted red, and the negative black. Possibly some other method of indicating may be taken, but in all accumulators of the same make the anodes will have the same appearance. This enables them to be easily coupled in series or in parallel at will.

Accumulators should be kept at a fairly even temperature, and should not be jarred more than is necessary. They should not be run down below a certain point, which can be ascertained from makers. To prevent running down the accumulators too much, it is almost absolutely necessary to have a voltmeter; though shift may be made by using an incandescent lamp, which takes the voltage that ought to be the minimum of your accumulator. Tests can be made with the lamp from time to time, and, when it is found to glow dull and red, the accumulator needs re-charging. Anyone who has a house-supply of continuous current electricity can easily re-charge his accumulators. But it will be necessary to have a wall-plug fixed by an electrician, and to take his instructions for charging. (See also the remarks of A. E. Livermore, on p. 22). If an accumulator is charged "the wrong way round" it will be ruined.

Having now our battery of primary cells or accumulators, we must attach them to the induction-coil. For this we need a few yards of gutta-percha-covered wire of No. 16 B.W.G. For connecting the coil to the tube

thinner wires may be used, such as No. 36 B.W.G. silk covered. These must not be handled while the current is flowing.

If using covered wires without proper connection ends, see that the covering is scraped away from sufficient wire to make a good connection, and that the wire is bright and free from oxidation. If your connection (on the battery) has a screw and a hole below, pass the bare wire point through the hole and tighten the screw. If there is a nut on a threaded upright pass the wire once or twice tightly round the upright, and screw down firmly. If only a loop is provided pass your connection through it and twist round.

In the same way fasten the other ends of your wire to the screw-connections that are found at one end of the induction-coil. In the ordinary coils there are only two such connections, but there are some in which four connections are supplied, so that the whole, or half the sections of the coil can be used at will; and in yet other forms of coil there are two connections which allow the coil to be used without the condenser, for alternating current work. If your coil has more than two connections their uses will be pointed out when you buy it, or you can easily find out by one or two experiments, or, better still, some electrician or electrical student will give a first lesson.

A commutator, a sort of double cam of ivory or ebony and brass, is part of all good modern coils. The cam works between two brass uprights, and when the ivory (or ebonite) part is touching them no current passes. When the brass sides are touching the uprights the current can pass in one direction, and when the commutator is turned completely over, so that the respective brasses touch the reverse sides, the current is reversed.

The **contact-breaker** is shown in detail in fig 20, and the instructions as to its use should be read with great care by those not accustomed to induction coils.

The tension-screw *d* has a double purpose. Its main one, often unrecognised, is to practically shorten the spring *b* by being pressed against it. The shortening of

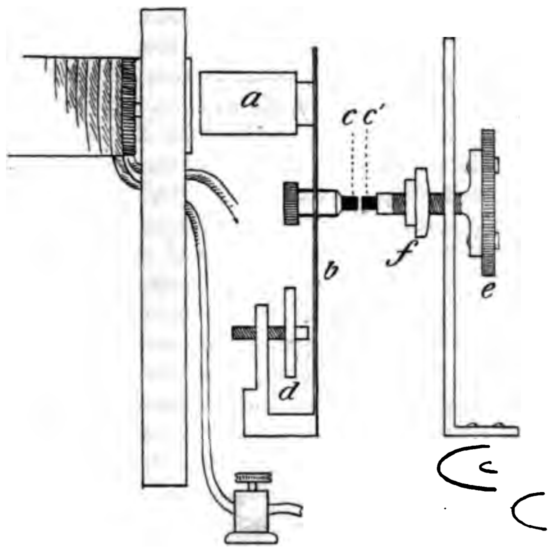

Fig. 20. Contact-Breaker.

a=hammer. *b*=spring. *c*. *c′* contact points. *d*=tension-screw. *e*=contact-screw. *f*=lock-nut.

the spring causes it to tend to vibrate more rapidly. Screwing this tension-screw strongly against the spring increases the length of spark obtained from the coil (within limits). With this tension off, and a fairly large gap between *c* and *c′*, the coil will run more sweetly, but the resulting spark is not so great. The

best radiographic results seem to be with a spark of two to three inches from a coil capable of giving at least double. That is, a two inch spark from a two inch coil will not give nearly such good results as a two inch spark from a six inch coil.

The action of the contact-breaker may be judged by its note; the shriller the note, the more rapid is the working, and, when the note is ragged and "sputtery," the screws want adjusting. The sputtering may indicate that the platinum contact-points have become partially fused and ragged, in which case they should be trimmed flat, with a stroke or two of a smooth flat file. Occasionally the points may fuse together. If this occurs during an exposure, or when you cannot immediately stop the work, draw back the hammer-spring, so as to break the fusion; and at the first convenient opportunity stop to file the points.

The platinum points will gradually fuse away; and when this has taken place there will be a considerable burning of the hammer-spring, which will soon be burned through, unless the platinum is replaced. Very few electricians keep platinum in any size, and therefore, I find, they usually solder on a bit of thick foil, a thing that lasts "no time." A good stout piece of platinum should be obtained (say 3-sixteenths in. or $\frac{1}{4}$ in. long, of wire $\frac{1}{8}$ in. thick), and this should be rivetted into the spring, with a similar piece into the contact screw. The only people I know who stock such patinum are Johnson and Matthey.

The current at the battery end of the coil is at such small tension that the sparks one is liable to take from the contact-breaker, though startling, are not dangerous. When the coil is worked for long, and the contact-breaker requires much adjustment of the tension screw, the heat may be painful to the fingers, so

that it is well to adjust the contact-breaker carefully at first, then screw it up and leave alone as much as possible.

The **connecting-wires** from the coil to the tube will be attached to the knobs provided on top of the coil or to the discharging-rods. This may be very fine wire, because the current is very small, though the tension is enormously high. The wire should be well insulated. And here I may remark that, though the current passing into the coil is fairly harmless, that passing out of the coil is **a very dangerous power.** All people unacquainted with electricity should be kept from loitering round the work-table, and the operator himself should work carefully, and keep his head cool. *The wires must never be touched when the current* is passing, except with a long glass rod. It may be that, inadvertedly, the operator may now and then touch one of the wires, and get what is known as a "capacity" shock; and that the immunity with which this is received may induce carelessness.

It is not wise to take even capacity shocks, but these are totally different from the passage of the current through the body, which occurs when both wires are touched at once.

If anyone is apparently **killed by electric shock**—the proper treatment is to lay them on damp flagstones, or a damp brick floor, and keep up artificial respiration, as in the case of the apparently drowned, meanwhile sending in hot haste for the nearest surgeon or physician. Sufferers are sometimes recovered after four or five hours of artificial respiration have been necessary.

The coil is highly electrified, and it is well, in the interests of coil and operator, not to touch or approach it (except at the contact-breaker) when the current is flowing. In the same way, the tube must not be touched and should not even be warmed with the spirit

lamp, when the current is passing. A touch is sometimes enough to draw a spark through the glass, after which the tube is useless.

To return from this digression The thin insulated wire, used to connect up the tube, may be made into a sort of spiral spring, by wrapping it round and round a glass rod (or even a lead pencil) and then sliding it off the end. In this form it will hang to the terminals of the vacuum tube, without the tendency to spring away that is found with straight wire. Half-an-inch at the end should be scraped free of the insulation, bent into a little hook and hung in the connecting loop of the tube. If one of these wires drops off when the current is running, *stop the current by use of the commutator before touching the wire.* If you have no commutator disconnect at the contact-breaker end before attempting to connect up at the other. In fact, as I said before, never touch your wire when a high-tension current is passing, or trying to pass through it.

The tube should be thoroughly dry, clean, and warm. If the weather is very cold or very damp, warm the tube gently in the flame of a large spirit-lamp, then wipe with a warm silk handkerchief. The flame must not be too near the tube, and must be kept moving. The connecting wires must not touch the tube, but run straight away from the electrode toward the coil. If the wire lies partly over the tube, or touches its side there is a possibility of a spark passing through the glass, instead of by the ordinary path to the electrode within, and this means the instant destruction of the tube. It is most important that the current should pass the right way through the tube, for, if the anode be made the cathode by mistake, there will be a rapid deposit of platinum black on the walls of the tube from the disintegration of the platinum foil. The re-

sult of this is a lowering of the vacuum, and a great deterioration of the tube. To determine which is the actual anode wire, leading from the coil, a test-paper may be used.

Current tests are numerous. Perhaps the simplest is to take a piece of strongly-colored litmus paper, wet, and lying on a glass plate. Place the ends of both wires (with the current trying to pass, of course) in contact with the paper, at a short distance apart. A red stain will form around the positive wire, and a blue around the negative wire.

Another excellent test, and one that is sensitive to very feeble currents, is a paper prepared with starch and an iodide.

Take—

Stiff starch paste	20 parts
Potassium iodide	1 part
Water	40 parts

and spread by means of a clean brush on paper. Dry, this will keep well. To use it, damp a piece of the paper, place the wires in contact with it, and a blue spot will appear at the positive wire. It may prevent confusion to remember that the wire connected with the positive plate of a battery is the negative wire, and that the positive wire, which is the one to be connected to the anode in the tube, is the one which comes from the negative plate of the battery. In fact, the negative plate of the battery is the positive pole, and in speaking of the positive wire, we mean the one from the positive pole.

It is well worth while to make a current test, and then carefully mark one of each pair of connections with a dab of red paint, or a bit of red silk. There should be a dab on the anode of the battery, and on the wire attached to it. The other end of the main lead wire should have one

The only other patterns of tube that a worke now likely to use are those shewn in accompany sketches, or modifications thereof. With these it not so necessary to carefully note the positive an negative wires, for though the tubes only work correctly when the current is passing the right way, a reversal does not damage the tubes, because both the electrodes are aluminium, which does not disintegrate.

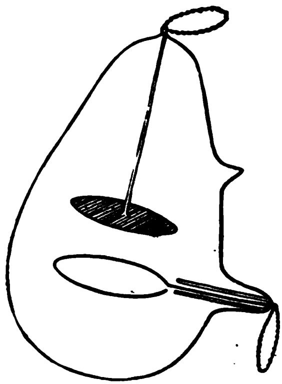

Fig. 22. Dr. Lewis Jones' Pattern.

Fig. 23. Early German Pattern.

When working rightly these tubes shew a bright patch of fluorescent glow playing all over their base. If the brightest glow is on the sides it shews that the current is passing the wrong way, and the commutator must be reversed.

The disadvantages of these tubes are that they re- quire from two to five or ten times the exposure necessary with focus tube, that they are much more subject to fatigue; and that the images they give are not

The only other patterns of tube that a worker is now likely to use are those shewn in accompanying sketches, or modifications thereof. With these it is not so necessary to carefully note the positive and negative wires, for though the tubes only work correctly when the current is passing the right way, a reversal does not damage the tubes, because both the electrodes are aluminium, which does not disintegrate.

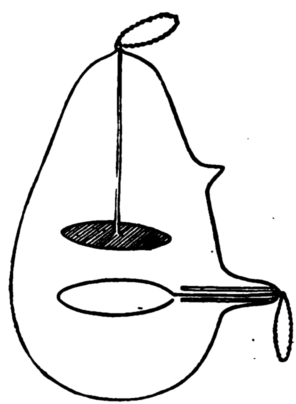

Fig. 22. Dr. Lewis Jones' Pattern.

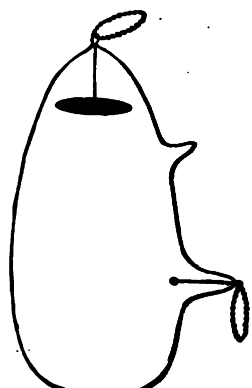

Fig. 23. Early German Pattern.

When working rightly these tubes shew a bright patch of fluorescent glow playing all over their base. If the brightest glow is on the sides it shews that the current is passing the wrong way, and the commutator must be reversed.

The disadvantages of these tubes are that they require from two to five or ten times the exposure necessary with focus tube, that they are much more subject to fatigue; and that the images they give are not

BY DR. MCINTYRE.
The Human Skull.

BY H. SNOWDEN WARD AND E. A. ROBINS.
Foot, with embedded needle.

so sharp in outline, because the X rays are produced from a large surface.

Professor Puluj's tube, a patented modification of an English pattern of more than ten years ago, has given wonderful results in the hands of Prof. Puluj; but, as it has only just been placed on the British market, I have not been able to use it personally. The sketch gives its construction, the anode (+) and cathode (—) are marked; and between them is a plate coated with a fluorescent salt, from which the X rays proceed. This plate should be placed parallel to the photographic plate on which the radiogram is to be made.

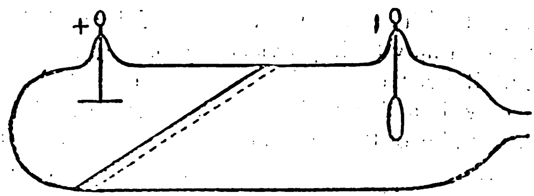

Fig. 24.

The ammeter is used by placing it in circuit between the battery and the induction coil. That is, instead of leading both your wires direct from the battery to the coil, lead one of them to one of the connecting screws of the ammeter; and another wire forward from the other connecting screw to the coil. When the current passes, the index of the ammeter will move over the scale. The constant interruptions of the contact-breaker will cause it to be wildly agitated, and to swing far past the point it intends to indicate. Still it swings equally on both sides, and you will easily be able to read the middle point covered as the measure of the current.

The Voltmeter is not placed in circuit, but wired

across from the positive to the negative leading wire; or from the positive to the negative terminal of the battery or condenser, by means of a very thin wire. Its finger is deflected and points to the voltage on an engraved scale.

Small breakages often occur; and it is an advantage for the radiographer to be handy with tools, and especially with a light soldering iron. Care will reduce the breakages to a minimum, and ordinary intelligence will suggest the most simple repair in most cases. One of the most annoying of these petty worries is when the tiny platinum connection to the tube gives way. It is impossible to solder any connection, so the tube-maker, in such cases, usually fits a little metal cap, attaching it with sealing wax. If no such cap is handy, a connection may be improvised by pressing a piece of thin tinfoil over the broken connection, and holding it in place with a dry rubber band. Keep the tinfoil as small as may be, or there will be sparking outside the tube.

The Wimshurst Machine has such advantages, in economy,—both from its own reasonable price, and from the fact of its not requiring an induction coil—that everyone is anxious that it should be proved satisfactory for radiography. As before stated, it has been successfully used by several workers, and appended are the brief instructions of Mr. Notcutt, of Ipswich, and Dr. Lawson Russell, of Todmorden, as communicated to *The Photogram* and *The Photographic News* respectively. Mr. Notcutt gives a little diagram (fig. 25) and suggests:

Two gaps, over which the sparks have to leap, are better than one, and one gap should be greater than the other. Leyden jars introduced do not make any improvement. They make the fluorescence brighter, but far more intermittent. The machine was a 24-in. double plate machine, giving 5-in. spark in air.

Dr. Lawson Russell says :—

"1st.—*The Surroundings.*—Have the temperature of the experimenting room at *not less* than 65° F., and the apparatus placed before good fire or stove. The air of the room must be free from dust and from moisture.

2nd.—*The Machine.*—The Wimshurst, besides being warm, must, like the air, be free from dust and adherent moisture. Its conducting rods should be in the position of greatest efficiency—that is they should be at right angles with each other, and should form an angle of 45° with the fixed collectors. It should stand firmly, and be driven steadily.

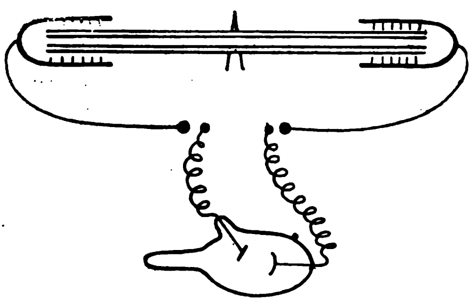

Fig. 25.

3rd.—*The Connections.*—The wires between the machine and the tube should be fixed to the terminal electrodes or dischargers close to the balls; they should be short, perfectly insulated, and the contact at the various connections should be perfect. If the wires are carried over or supported on anything on their way to the tube, let it be glass.

4th.—*The Tube.*—The typical tube for use with the Wimshurst is one of small dimensions, having a very high vacuum. It should be perfectly insulated, and on a

steady stand. Heat the tube before the fire or with a spirit lamp before beginning the exposure, and if, during the exposure, the current shows the slightest disinclination to pass through the tube, stop and heat the tube again with the spirit lamp. If the tube be one having a very high vacuum, this may require to be done every half-minute. The make of tube best adapted for use with the Wimshurst is, I find, that known as the 'focus' tube."

The use of the **Tesla Coil**, instead of, or in addition to, the induction coil has been strongly recommended and strongly condemned. For anyone who is not well acquainted with electricity the better plan is to leave it alone.

Instantaneous Work has great attractions, and must prove of enormous value in dealing with objects in motion, such as the living heart. For weeks the various workers were gradually reducing the time of exposure from an hour or so down to ten minutes, then, with a jump, to two minutes, then, gradually, to twenty and fifteen seconds, and then, at one bound, it dropped to a minute fraction of a second. This result was obtained by Dr. McIntyre, of Glasgow, who communicated to *The Photogram* on May 11th, as follows:—

Instantaneous radiograms can be got by a slight modification of the apparatus with the ordinary Crookes' focus tube. From a number of observations made on reading the current as measured on Lord Kelvin's ampere gauge while the coil was in action, I was able to show that with a mercury interrupter, properly adjusted, a much larger current passed through the primary coil, which naturally gives higher induced currents in the secondary and therefore more brilliant fluorescence, and greater actinic power. I have radiographed the bones of the hand and other objects with one flash of the tube, due to a single inter-

ruption of the eleven inch spark coil. What the time of exposure was no one can tell, but it must be an unknown and exceedingly small fraction of a second. I find the pictures obtained by instantaneous exposures are much better defined than anything I have yet done. With ten flashes of the tube I obtained better definition of the bones of the hand than in any radiogram I have ever taken with longer exposure.

This branch of the work is subject to much careful experiment, and further particulars may be expected from any of our investigators. Meanwhile, I may point out how the ordinary contact-breaker may be used for "flashing." Screw up the tension screw so that the hammer is pressed away from the core so far as to prevent a spark passing. Wire up to a good battery power—more than you would dare to pass continuously into the coil—and make the flash by pressing the hammer towards the core until a single spark passes. Too many such sparks must not be passed in succession or the coil will heat, and its insulation and usefulness come to an end.

The voltage, reckoned by the length of spark in air at ordinary pressure, may be taken (according to Gordon and Alexander Siemens), as 30,000 volts per centimetre, if the sparking is between ball dischargers. If the sparking is between points, a greater length may be obtained with less voltage, so that a centimetre spark will be a measure of from 20,000 to 25,000 volts. This is about equivalent to 55,000 volts per inch, so that a six-inch spark between points indicates a tension of over 300,000 volts.

CHAPTER VI.

Practical Radiography:—Photographic.

To attempt to teach the whole of photography in this little book would be as hopeless as to attempt to teach the whole of electricity. The instructions which seem indispensable are given, but a further knowledge of both subjects is very desirable, and as I referred the would-be electrician to a hand-book, I now refer the would-be photographer to "Early Work in Photography," price 1s., post free 1s. 3d., published by the same firm as the present little book.

The dark-room, which must be used for developing photographic plates, is really a room lighted by ruby light. No trace of white light must be admitted. It may be illuminated by a ruby lamp (obtainable from the photo-material dealers) or by part of a window covered with a thickness of ruby and a thickness of canary fabric. If the window is exposed to sunshine an extra thickness of ruby is advisable. The dark-room must be provided with the dishes, &c., that were previously mentioned, and should have a supply of running water. As pyrogallic acid is a capital dye (it is the basis of the most generally-used hair-dye) it will be well to keep the developer off any towels, tables, &c., that it is wished to preserve from stain. Pyrogallic acid is the basis of our developer—hence this caution.

The developer consists of three essential parts—density giver, accelerator, and restrainer. There are almost innumerable formulæ, some of which are perhaps

better than the one here given, but this is chosen because of its simplicity:

DENSITY GIVER.

Pyrogallic Acid...	... ...	¼ ounce
Potassium Metabisulphite	...	5 grains
Water to make ...	... ...	10 fl. oz.

ACCELERATOR.

Potassium Carbonate	... ...	1 ounce
Water to make ...	... ...	10 ounces

RESTRAINER.

Potassium Bromide	... ...	1 ounce
Water to make ...	... ...	10 ounces

The accelerator and restrainer can be kept in solution in properly-stoppered bottles for an indefinite time. The density giver will keep for a week or two.

The fixing-bath will consist of

Sodium Hyposulphite (hypo.)	...	4 ounces
Water ...	... ...	10 ounces

It is not necessary for the proportions of the fixing-bath to be absolutely correct.

These things should be ready in the dark-room before beginning to make exposures.

The dry-plates must not be opened in white light, but in the dark-room the box may be opened, and the plates examined. It will be seen that the sensitive side has a film of slightly matt gelatine, while the glass will show a gleam when held slant-wise toward the red light. It is necessary that the sensitive side should be next to the object to be radiographed, and it is well to make a regular practice of putting this side toward the back of the inner bag; and to put the inner bag into the outer bag in the same way. When the plate is laid on the table, the flaps of the bags and the gummed folds will be underneath, while over the sen-

sitive surface there will be nothing but the two perfectly flat papers forming the backs of the bags. Lay one of the plates, thus protected, on the table beneath the vacuum tube, and let your first experiments be made with coins or keys—things that are very opaque to the X rays.

The exposure depends much upon the tube and coil, and how they are working. Using the current I have suggested, and getting a three-inch spark from the secondary coil, a good focus tube should give a fully exposed image in fifteen to thirty seconds, but it will be well, at first, to give a minute. That is to say, the plate should be laid under the tube for a minute, during which the current is passing through the tube, and the tube fluorescing brightly.

After the exposure take the plate, still in its envelopes, to the dark-room. There close the door, so that no white light can come in; and mix the following developing solution :—

Density giver (pyro.)	1 fl. drachm
Accelerator (carbonate) ...	1 "
Restrainer (bromide)	20 drops
Water	6 fl. ounces

This should be mixed in the measure, then the plate is taken from its envelopes, and laid, sensitive side upward, in one of the vulcanite dishes. Sufficient of the mixed developer to cover it should be flowed over in an even wave, beginning near one corner. If it does not *immediately* flow all over the plate, the dish must be rocked gently to cause it to do so, or the result will be a streaky negative. The developer must be flowed, and not splashed on to the plate, or air-bubbles will be formed which will cause spots on the negative if allowed to rest long on any one part. The dish may now be held so that the ruby light falls upon it, and

should be gently rocked too and fro. In about thirty seconds, or from that to a minute, the plate should begin to change slightly from its creamy-white appearance to a grey, except on the spots that were under the coins. The greyness will gradually grow deeper and deeper until it becomes almost black, and even after that point is reached the development may be continued, so long as the spots that were under the coins remain creamy. When the greyness can be plainly seen on turning over the plate and looking at the glass side, the development may be stopped. The plate should be rinsed in clean water to free it from the developer, and then placed, glass downward, in the fixing bath.

In the Fixing Bath the plate will remain until the parts that were left creamy by the developer have become quite transparent, and for at least two or three minutes longer. It is then removed, washed by soaking for half-an-hour in several changes of water, or better still, in a dish into which a tap is dribbling. After washing, the plate can be stood on its edge against a wall, or in a proper draining-rack to dry: but it must not be dried by heat.

Quick Negatives may be secured, if it is not necessary that they should be very permanent, by giving them just a slight rinse after fixing, then transferring them for two or three minutes to a dish of alcohol, after which they can be dried rapidly by fanning in front of a fire, but not too near the heat. The spirit replaces the water in the film, and dries rapidly by evaporation.

I have supposed that the exposure was correct; but it may be that the tube was not working well, or that the plate was not sufficiently sensitive, and that therefore the plate was **under-exposed**. In this case instead of a greyness beginning to appear in a minute or less,

you may wait three or four minutes, and yet see little or no trace of change. In this case add a little more of the accelerator. Measure one drachm into a glass graduate or a cup, and pour the mixed developer from the plate into it, then flow over the plate again. Even more of the accelerator may be needed, and in such a case the completion of the development will be slow.

In the case of **over-exposure** the greying will commence almost immediately the mixed developer is flowed over the plate, and it will continue very rapidly. In such a case the developer must be *at once* poured off, and two or three times the original amount of restrainer be added to it before it is poured on again.

With coins and keys over or under exposure makes very little difference to the result; but when you come to subjects in which there is no such intense contrast as between the very dense objects and the very transparent paper of the bags, the case is different. When you radiograph a hand, in which the difference of opacity between bone and flesh is relatively slighter, much greater accuracy of exposure is necessary. If there is great under-exposure you will be able to develop an image of the flesh of the hand contrasted with the unprotected plate, but with very little difference between the flesh and the bone. If there is gross over-exposure the flesh will shew little or no sign, but the rays will have penetrated to some extent, even through the bone, so that there is no vigor or contrast in the result.

Those who go far into radiography will doubtless wish to make **Prints or Lantern Slides** from their originals, and I hope they may be tempted to go thoroughly into photography, but the instructions, beyond the making of the original, seem to belong to a photographic rather than a radiographic handbook.

CHAPTER VII.

PRACTICAL RADIOSCOPY.

RÖNTGEN observed that when the X rays fell upon a card coated with barium platino-cyanide, the salt glowed in darkness. He also noted that if the hand were held between the radiating tube and the screen, a distinct shadow of the bones was cast. And further, as the X rays could penetrate cardboard, the hand could be placed behind the screen, and the shadow of the bones would be seen in front.

This is the basis of the **Cryptoscope, Iristoscope, Fluoroscope**, or **Radioscope**, whichever we may call it, simply a fluorescent screen set in the bottom of a box or protection so that it may be shielded from light, and its faint glow and shadow be observed without having to make the whole room dark. We will consider the best method of making such a screen, under the headings of the fluorescent salt, the support, the medium, and the finishing.

The advantage of the screen is that you can *see* the shadow of whatever object you wish to investigate, without going to the trouble of exposing a plate and developing a negative. The advantage to the surgeon is very great in some cases—as when a foreign substance is in the wind-pipe—because he can see not only the foreign body, but also the instrument which he is guiding for its extraction.

Many fluorescent salts are known. They may roughly be described as bodies possessing the property

To make the screen, have everything ready, so that the work may be carried through quickly. Coat the support quickly and evenly with the medium. See that it is not lumpy or streaky, and that it does not have time to dry in patches. As soon as the medium is well spread, dust over it the salt from a fine sieve of silk, or better, of wire gauze. Take the support by one corner or side and hold it up for a moment, so that any non-adherent particles may fall off, and then go over it with a little more of the salt, working it in with the fingers if necessary, to cover any bare spots. As the platino-cyanides are so expensive, the dusting should be done over a tray, so that nothing may be lost. After the dusting is completed, the screen should be allowed to thoroughly dry, and should then be lightly brushed over with a soft camel-hair brush to remove loose crystals. If the coating is not even, it can be amended by going over the bare places with a little of the medium, and again dusting with the salt; but every effort should be used to make a good screen at the first operation. To complete the screen it is advisable to frame it in a light frame, with a good piece of glass or a sheet of transparent celluloid in front.

A screen on glass can be made with a very fine even surface; and as the glass side will be turned away from the tube the imperviousness of the glass to the X rays is no disadvantage. Such a screen requires no other glass in the frame to protect it, only a sheet of fine card in the back to obstruct the light-rays from the tube. The fault of such a screen is that, if the glass gets broken, the fluorescent salt is practically irrecoverable, whereas, when a less brittle support is used, the breakage of the covering-glass is no great loss.

Flexible screens have certain advantages, especially

when attempting an observation through the thickness of the human body; and these may best be made by using thin black celluloid as the support for the salt, and thin transparent celluloid for the cover. Such are the screens sold by W. Watson & Sons.

The radioscope is made by applying one of these screens to any form of box that will enable the screen to be seen, and will shut out all light. For surgical purposes, probably the most convenient form is the one

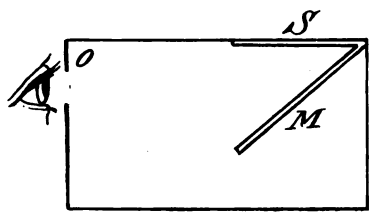

Fig. 26.

shewn in end section in the diagram, in which S is the screen, with its fluorescent side downward; M is a mirror, set at an angle of 45°, and O represents one of two openings for the eyes of the observer. In this case the part to be examined is laid on the screen. Edison's pattern is exactly like a closed hand stereoscope, the screen occupying the position usually assigned to the stereoscopic slide, and the sides of the eyes being well protected. To use this form the tube must be placed beneath or behind the object.

A Hand Radioscope in a form that is handsome and very convenient for surgical work was placed on the market by Newton & Co., who have also been the first introducers of several pieces of useful apparatus—including the "focus" tube. This radioscope is circular

in form and is framed in the silvered rim of a hand mirror.

Phosphorescent screens may eventually be found to have advantages over those of fluorescent nature. For popular purposes the difference may be said to be that fluorescent screens glow only while the rays are actually falling upon them, whereas phosphorescent screens, once excited, continue to glow for some time. The phosphorescent screen, too, should have a cumulative effect; so that an image which is only dimly seen at first, and dimly seen on the fluorescent screen, will become gradually brighter and brighter under long exposure. An image that can be examined for a few minutes, even, without keeping the vacuum tube glowing, and the object and screen in a fixed position, would have decided advantages; and I am tempted to hope that this may be possible by the recent manufacture (it is not yet on the market) of a wonderfully brilliant sample of calcium sulphide (the basis of Balmain's luminous paint). This is in the hands of W. C. Horne, the proprietor of the paint, from whom I have received samples for testing, and with the aid of Thomas Bolas, F.C.S., F.I.C., perhaps our best practical authority on phosphorescent substances, I trust a successful screen may be possible.

The decrease of exposure by means of a fluorescent screen has been suggested, and very successfully carried out by some of the German workers. A screen is introduced into the light-tight bag, or other receptacle for the plate, the sensitive surface of the plate being towards the fluorescent surface of the screen. In this case the X rays have to pass through the glass of the plate to the film, but the glass is found more pervious than the fluorescent salt, otherwise the whole arrangement could be reversed. In this method of working the perviousness of celluloid

is a great advantage, and a sensitive emulsion on celluloid will be better than the same on glass. The fluorescence of the screen supplements the X rays in their reducing action upon the silver salts, so that the exposure is reduced to half or one-third of the amount ordinarily required. The only disadvantage is the granularity of the screen, which causes a certain granular appearance in the radiogram. Least of this trouble is found with the calcium tungstate screen.

CHAPTER VIII.

Applications and Probable Advances.

THE matter of this chapter can scarce be arranged in any consistent order. Various applications of the X rays have already been incidentally mentioned, and certain probable advances have been hinted at.

The theory of the X rays has already led to much discussion. Physicists have long dreamed of a force akin in some of its characteristics to the X rays, which should consist of longitudinal vibrations (as distinguished from the undulating vibrations to which heat and light are attributed) of the ether. There is an inclination in some quarters to suppose that the X rays may be such longitudinal vibrations. That they are ultra ultra-violet light undulations of immense rapidity but very short length, is held by some. Edison suggests that they are of the nature of sound-waves rather than light; while Tesla sees some reason to think that they are streams of electrified particles, similar to the radiant matter, or cathode rays within the vacuum tube. An elaborate argument on the *pros* and *cons* would be out of place here; and the evidence is accumulating day by day, so that the balance in favour of one or other theory is constantly changing.

The surgical applications are far the most important up to the present; and in this connection the most important immediate advances are to be expected. By radiography and radioscopy an immense number of surgical operations can be assisted or rendered unnecessary. When a foreign substance has entered the flesh, it is often

difficult, and sometimes impossible, even when the surgeon is called immediately, for him to trace the substance by probing, but radioscopy reveals its position at once. The hand with supernumerary thumb, which appears on the cover, was radiographed, with the assistance of Julius A. Kay, the photographer, of Southport, to show the surgeons of the local infirmary what was the exact bone formation, and to enable them to decide whether amputation of the supernumerary thumb was advisable. In a case at Sunderland, a needle lost in a child's foot (see p. 56) was plainly revealed by radiography, and successfully extracted the next morning, though previously the surgeon had probed without finding it. A case we had at Dewsbury was that of a young woman who had lost a piece of needle in her wrist, and said she could still feel it there, though the surgeon could not find it. We radiographed the hand and wrist, and secured a radiogram shewing every detail of the bone, but no trace of the needle; so another radiogram, from wrist to elbow was made, and showed that there was no needle in that section. The foreign substance had travelled, painlessly, as needles in the muscles often will, some distance from the point of entry, but the nerve, slightly injured at the entry spot, still felt pain as if the needle were there. Wrists and ankles, when there is doubt as to whether an injury is a fracture or a dislocation, can be easily investigated. Gouty symptoms, disease of the bone, and many other troubles can already be plainly seen. In obstetrics the enormous value of radiography must be obvious, upon reflection.

The nervousness of patients is one of the difficulties in surgical work; and where the subject is afraid of the apparatus it is well to show the tube running for a little while, with the operator's hand beneath it. It is very necessary, also, to convey the wires from the coil to tube in such a way that there is no chance of the patient

CHAPTER VIII.

Applications and Probable Advances.

THE matter of this chapter can scarce be arranged in any consistent order. Various applications of the X rays have already been incidentally mentioned, and certain probable advances have been hinted at.

The theory of the X rays has already led to much discussion. Physicists have long dreamed of a force akin in some of its characteristics to the X rays, which should consist of longitudinal vibrations (as distinguished from the undulating vibrations to which heat and light are attributed) of the ether. There is an inclination in some quarters to suppose that the X rays may be such longitudinal vibrations. That they are ultra ultra-violet light undulations of immense rapidity but very short length, is held by some. Edison suggests that they are of the nature of sound-waves rather than light; while Tesla sees some reason to think that they are streams of electrified particles, similar to the radiant matter, or cathode rays within the vacuum tube. An elaborate argument on the *pros* and *cons* would be out of place here; and the evidence is accumulating day by day, so that the balance in favour of one or other theory is constantly changing.

The surgical applications are far the most important up to the present; and in this connection the most important immediate advances are to be expected. By radiography and radioscopy an immense number of surgical operations can be assisted or rendered unnecessary. When a foreign substance has entered the flesh, it is often

lt, and sometimes impossible, even when the surgeon ed immediately, for him to trace the substance by ıg, but radioscopy reveals its position at once. The with supernumerary thumb, which appears on the was radiographed, with the assistance of Julius A. he photographer, of Southport, to show the sur- of the local infirmary what was the exact bone tion, and to enable them to decide whether ampu- of the supernumerary thumb was advisable. In a t Sunderland, a needle lost in a child's foot (see p. 56) laiılly revealed by radiography, and successfully ted the next morning, though previously the surgeon obed without finding it. A case we had at Dews- vas that of a young woman who had lost a piece of in her wrist, and said she could still feel it there, h the surgeon could not find it. We radiographed nd and wrist, and secured a radiogram shewing every of the bone, but no trace of the needle; so another ram, from wrist to elbow was made, and showed here was no needle in that section. The foreign nce had travelled, painlessly, as needles in the es often will, some distance from the point of entry, e nerve, slightly injured at the entry spot, still felt as if the needle were there. Wrists and ankles, there is doubt as to whether an injury is a fracture dislocation, can be easily investigated. Gouty oms, disease of the bone, and many other troubles ready be plainly seen. In obstetrics the enormous of radiography must be obvious, upon reflection.

nervousness of patients is one of the diffi- in surgical work ; and where the subject is afraid apparatus it is well to show the tube running for a while, with the operator's hand beneath it. It is necessary, also, to convey the wires from the coil to n such a way that there is no chance of the patient

CHAPTER VIII.

APPLICATIONS AND PROBABLE ADVANCES.

THE matter of this chapter can scarce be arranged in any consistent order. Various applications of the X rays have already been incidentally mentioned, and certain probable advances have been hinted at.

The theory of the X rays has already led to much discussion. Physicists have long dreamed of a force akin in some of its characteristics to the X rays, which should consist of longitudinal vibrations (as distinguished from the undulating vibrations to which heat and light are attributed) of the ether. There is an inclination in some quarters to suppose that the X rays may be such longitudinal vibrations. That they are ultra ultra-violet light undulations of immense rapidity but very short length, is held by some. Edison suggests that they are of the nature of sound-waves rather than light; while Tesla sees some reason to think that they are streams of electrified particles, similar to the radiant matter, or cathode rays within the vacuum tube. An elaborate argument on the *pros* and *cons* would be out of place here; and the evidence is accumulating day by day, so that the balance in favour of one or other theory is constantly changing.

The surgical applications are far the most important up to the present; and in this connection the most important immediate advances are to be expected. By radiography and radioscopy an immense number of surgical operations can be assisted or rendered unnecessary. When a foreign substance has entered the flesh, it is often

fficult, and sometimes impossible, even when the surgeon called immediately, for him to trace the substance by obing, but radioscopy reveals its position at once. The .nd with supernumerary thumb, which appears on the ver, was radiographed, with the assistance of Julius A. ay, the photographer, of Southport, to show the sur-:ons of the local infirmary what was the exact bone rmation, and to enable them to decide whether ampu-tion of the supernumerary thumb was advisable. In a ise at Sunderland, a needle lost in a child's foot (see p. 56) as plainly revealed by radiography, and successfully tracted the next morning, though previously the surgeon id probed without finding it. A case we had at Dews-iry was that of a young woman who had lost a piece of :edle in her wrist, and said she could still feel it there, iough the surgeon could not find it. We radiographed .e hand and wrist, and secured a radiogram shewing every :tail of the bone, but no trace of the needle; so another diogram, from wrist to elbow was made, and showed at there was no needle in that section. The foreign bstance had travelled, painlessly, as needles in the uscles often will, some distance from the point of entry, it the nerve, slightly injured at the entry spot, still felt in as if the needle were there. Wrists and ankles, ien there is doubt as to whether an injury is a fracture a dislocation, can be easily investigated. Gouty mptoms, disease of the bone, and many other troubles n already be plainly seen. In obstetrics the enormous lue of radiography must be obvious, upon reflection.

The nervousness of patients is one of the diffi-lties in surgical work; and where the subject is afraid the apparatus it is well to show the tube running for a tle while, with the operator's hand beneath it. It is ry necessary, also, to convey the wires from the coil to be in such a way that there is no chance of the patient

receiving a capacity shock, for one such shock is often enough to destroy all confidence. A word of caution against touching the tube should be given, and care must be taken to have the tube so far above the part radiographed that there in no chance of a spark to or from the tube. I have known an operator send a constant succession of sparks from the leading-in wire to the hand of a patient, from the false idea that it was necessary to have the tube very close to the hand in order to give a sufficiently short exposure. In any case, with the tube too close, sharpness of outline is entirely lost, and it is possible for such an object as a needle to remain undiscovered because its shadow is all penumbral.

With a child or a nervous woman it is well for someone, preferably the surgeon, or someone known to the patient, to lay a hand gently and soothingly but firmly on the part to be radiographed, both for the sake of giving confidence and preventing involuntary movement. With a child's foot it is well to firmly grasp the leg between calf and ankle, and to lay the fingers over the tips of the toes. An example of this kind is reproduced.

The clothing need seldom be removed except boots with nails or irons, or dresses stiffened with steel or thick whalebones. Clothing should be removed if necessary to enable the part to be brought close to the dry plate ; and if searching in the body for a bullet it is well to see that suspender buttons are not in the field.

Splints may remain if they are of wood, and bandages are perfectly pervious to the rays. In fact when a patient cannot be prevailed upon to keep fingers or toes still, it is sometimes necessary to tightly bandage them to a flat board, with the plate either over or under the board.

Germicidal powers were early claimed for the *x* rays, on the supposition that the rays were of the nature of

ultra-violet light, which has a destructive effect on bacteria. Dr. Glover Lyon reported to the Royal Photographic Society that he had subjected gelatinous cultivations of various bacteria to the influence of the *x* rays for a long period, with only the effect that the bacteria throve exceedingly. Since then, three Chicagoan Professors have announced the germicidal powers of the rays, but, apparently, not from experimental data.

Medicinal value is claimed by Dr. T. S. Middleton, of New York, who does not believe in the germicidal properties, but thinks that the rays consist of streams ot material particles, and can be used to convey medicinal matter and deposit it at the actual seat of the disease, thus enabling consumption and cancer to be cured.

A plan and elevation are necessary to locate exactly any foreign body. For instance, if a bullet is embedded in the thigh, it is necessary to make one radiogram (or radioscopic observation) from the front or back, and one from the side. Measurement on two such observations will locate the shot exactly.

A triangulation method may also be adopted, by using two tubes at a slight distance apart, so that two shadows may be cast upon one screen or dry plate. By measuring the relative positions of tubes, subject, and screen, lines may be drawn from the shadows to the tubes, and will cross exactly at the position of the object casting the shadows. This method is perhaps better adapted for radioscopy than for radiography, but in both cases the confusion of image introduces a difficulty.

The fleshy structures are now to be differentiated, since radiographv has been so far perfected that every part of the adult human skeleton has been radiographed. The sole, by A. A. Campbell-Swinton, in which the air-sac came out distinctly, was the first radiogram in which flesh-differences were shown, and Dr. McIntyre on the

human frame, and J. W. Gifford on rats, &c., took up this special branch of the work. The human heart, represented in the frontispiece, is the greatest triumph, up to date, in this direction.

Contents of packets. The Post Office and Customs Offices have found radioscopy very valuable in detecting coins concealed in letter packets, watches and other contraband articles in books, &c., &c. The detective force, too, both in Paris and London, have found the method useful for revealing the contents of certain suspected packets, which have proved to be infernal machines. It has been stated that letters can be read by means of the *x* Rays—and so they can when specially prepared for the purpose; but a letter written on four sides and then folded into two or three is quite safe from *x*-ray prying. And besides, the opening and re-sealing of a letter is so simple that if anyone wished to pry they would be quite unlikely to trouble with the *x* Rays.

Flaws in metals, and bad alloying may be detected by radiography, but hardly to any useful extent at present, because the metals we most wish to test are impervious to the rays if in any useful thickness. Still there seems no real reason why radiography should not be so far improved as to enable boiler-plates and even thicker iron sheets than these to be tested by the *x* Rays. It is a most important field of research, and one in which, so far as I am aware, no one is working.

False gems may, in many cases, be detected by their *x*-ray transparency or opacity. Thus—diamonds are much more transparent than "paste," and when placed side by side, the "paste" will throw a distinct shadow. Imitation pearls and many other gems may be similarly detected.

The value of cattle-food for bone-forming purposes is being studied with the help of radiography. Sets of

animals, carefully fed on different foods, are radiographed at various periods in their growth, and the radiograms or their skeletons compared.

Radiographing the skull is not difficult, though radiography of the brain will probably long be impossible. When one side of the skull is laid on the dry-plate, very beautiful detail of its structure can be obtained by long exposure, for the side near the tube is so far from the plate that it casts no distinct shadow. Tesla says that when the rays are thus passing through the brain there is a sense of sleepiness; while another worker has reported that the use of the vacuum tube close to the head causes the hair to fall out. The skull of which part is reproduced, from a radiogram by Dr. McIntyre, was that of a dead person.

Any question that depends upon the varying *x* ray opacities of different substances, can, of course, be solved by radiography. It only remains for those who have such questions in their varying trades, professions, or pursuits, to make the applications.

Meanwhile, a little army of workers is busy in all parts of the world, investigating the nature and properties of the *x* rays themselves, and endeavouring to increase their power and efficiency. There are hundreds of questions which require patient research to finally answer. We want more knowledge as to the best electrical, photographic, and mechanical conditions. The arrangements of batteries and induction coils (or Wimshurst and spark-gap) are by no means final. The construction of the tube; and especially its best extent of exhaustion are still subject to revision. On the best formulæ for the dry-plates and developer we still want much light. On all these points investigators are at work, but there is ample room for many times the number.

To all the leading workers we are greatly indebted

for information and assistance freely given to all who wished to enter on the same lines. Their valuable discoveries have been freely made public, and I trust that the tendency to secretiveness,—of which some signs are appearing—may meet with no encouragement.

Any of the techical journals dealing with photography, electricity or surgery, will provide a means of communicating radiographic matter to the public. Any practical communications that may be addressed to myself will be copied and sent direct to such workers as I know to be interested in the particular matter; or, if preferred, and the matter seems suitable, they will be communicated to the Press Associations and News Agencies for transmission to the general Press. Such work will also, as far as possible, be included in any future editions of this little book, and also in the monthly issues of *The Photogram*.

NEWTON & CO.